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Growth of a *Paramuricea clavata* population (Risso, 1826) (Gorgonacea, Paramuriceidae) in Quercianella area (Leghorn, Tuscany)

Abstract - The present study of the growth of *P. clavata* was conducted for three consecutive years (2000-2003) in an area at 26 to 35 m depth, offshore of the Romito bridge (Quercianella, Livorno (Leghorn) – southern Ligurian Sea).

The diameter, height and shape of the colony were measured in 81 marked colonies, while other biometric parameters (fibre length, effective area, roundness, etc.) were recorded by photography and analysed by computer (Quantimet program).

The average annual rates of growth in height and in fibre length were 3.2 ±2.6 cm and 37.07 ±16.04 cm respectively. The increase in growth was greater in winter (October-March) than in summer (April-September).

In addition to the contribution of new data on the biology and growth of *P. clavata* on the Tuscany coast, the innovative element of this research is the use of non-invasive techniques that avoid the removal of colonies, combined with subsequent laboratory analyses.

Key words: Celenterates, *Paramuricea clavata*, growth, Ligurian Sea.

Riassunto - Crescita di una popolazione di *Paramuricea clavata* (Risso, 1826) (Gorgonacea, Paramuriceidae) nell'area di Quercianella (Livorno,Toscana).

Lo studio, volto ad analizzare la crescita di *P. clavata*, è stato condotto per tre anni consecutivi (2000-2003) in un'area antistante il ponte del Romito (Quercianella, Livorno - Mar Ligure meridionale) ad una profondità compresa tra i 26 ed i 35 m.

Su 81 colonie marcate sono stati misurati: il diametro, l'altezza, la forma ed altri parametri biometrici (lunghezza-fibra, area effettiva, rotondità, etc.) ottenuti con la tecnica fotografica e la rielaborazione computerizzata delle immagini tramite il programma Quantimet.

Il tasso di crescita annuale medio è risultato pari a 3,2 ±2,6 cm per l'altezza e di 37,07 ±16,04 cm per la lunghezza-fibra. Inoltre l'incremento stagionale del tasso di crescita risulta maggiore da ottobre a marzo rispetto al periodo da aprile a settembre.

Oltre all'apporto di nuovi dati sugli aspetti biologici e sulla crescita di *P. clavata* nell'area costiera toscana, l'elemento innovativo di questa ricerca è da ricercarsi nell'uso di tecniche non invasive che hanno evitato l'asportazione delle colonie e la successiva analisi in laboratorio.

Parole chiave: Celenterati, *Paramuricea clavata*, crescita, Mar Ligure.

Introduction

Paramuricea clavata (Risso, 1826), belonging to the order Gorgonacea

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(Anthozoa, Alcyonaria), is a sciophilous species (Chapman & Theodor, 1969; Weinberg, 1975, 1978, 1991; Gili & Garcìa, 1984), distributed in the Mediterranean area, usually on vertical substrata (Weinberg, 1979a) of coralligenous nature (Pérès & Picard, 1964; Gili, 1981; Mistri & Ceccherelli, 1994). The characteristic dark red colonies (Weinberg, 1976) present a typical arborescent form, developing mainly in a plane with dichotomous and very flexible drops (Carpine, 1963).

The aim of the present study was to evaluate the rate of growth of *P. clavata* using an innovative method based on the *in situ* collection of biometric data and the use of photography followed by computerized data processing with the Quantimet program. With these techniques, it's not necessary to remove the colonies. Therefore, research on these organisms can be conducted in full respect of basic conservation principles.

Materials and methods

The study area was situated 300 m offshore of the Romito bridge south of Livorno (Leghorn, Tuscany, Italy), at 43°27'724 N, 10°20'489 E, and at 26.4 to 33 m depth. It was chosen on the basis of its morphology, the depth of the bottom and the species abundance.

Three vertical transects (9 m long) were laid on the bottom, parallel to each other and 3 m apart. Three squares (1 m for side) were chosen at the ends and the centre of each transect, as representative samples of three different bathymetric zones.

Inside each square, we marked 9 colonies (more than twice average value for each square) for a total of 81 colonies. On the basis of previous reports, we decided besides to divide the colonies into three size classes: small (< 20 cm), medium (≤ 35 cm) and large (> 35 cm).

During the three years of research (September 2001 - March 2003), the height of each colony was measured (with a rigid ruler) every 6 months, while the basal diameter was measured annually (with a decimal scale calliper) 3 cm from the attachment point. Given the almost elliptical shape of the central axis of the *P. clavata* skeleton (Mistri, 1995), we measured both the maximum and minimum diameters. In addition, we carried out a photographic survey using a panel with a 5-cm grid as a size reference. The colour photographs were subsequently transformed into grey-scale images (bitmap) (Fig.1) by Photoshop (computer program) and analysed with the Quantimet (computer program). The computer analyses provided numerous biometric parameters, including:
- Fibre length, the amount of the lengths of all colony arms, calculated as:
$$\text{Perimeter} + (\text{Perimeter}^2 - 16*\text{Area}) / 4$$
This gives the approximation of the length of curved fibres (Quantimet 500 Operator's Manual: A-15).
- Roundness, index of roundness of the colony, calculated as:
$$\text{Perimeter}^2 / \text{Area}*4*\Pi*1.064$$
With 1.064 correction factor (Quantimet 500 Operator's Manual: A-17).
- Area, number of pixels, corresponding to the effective space occupied by the colony (Quantimet 500 Operator's Manual: A-14).
- Length, the distance between two chosen points.
From the photographic survey, we also recorded the shape of each colony, distin-

guishing between square, rectangular and feather-shaped according to the height/width ratio, calculated with the aid of the calibrated panel.

Statistical analyses

• The Pearson test was used to assess the significance of correlations between parameters.

• The average annual rate of growth was calculated by analysing the data normalized according to the average frequency of growth.

• The estimates of variability next to the average values represent the 95% confidence limits.

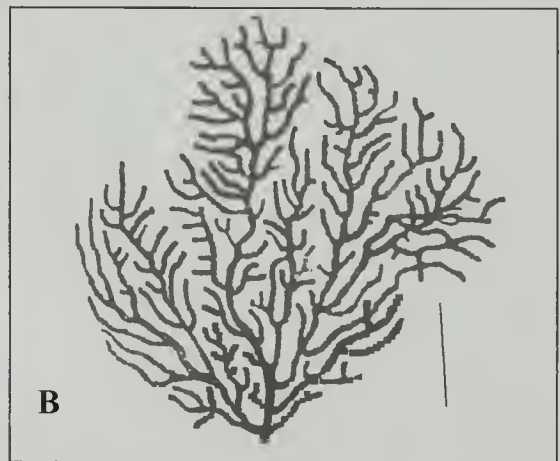• The t-test was used to assess differences between the averages.

Fig. 1 - A: original photography; B: photography modified by Photoshop in grey scale (bitmap) for Quantimet analysis. (Marco Borri).
Fig. 1 - A: fotografia originale; B: fotografia modificata con Photoshop in scala di grigio (bitmap) per l'analisi al Quantimet. (Marco Borri).

Results

Diameter

The correlation between the maximum and minimum diameters is very high (df=76, r=0.9 and P<0.01) (Fig. 2).

In same cases we observed a relative data dispersion, attributed to the presence of a fork straight above the base of colony. So we analysed the correlations between the minimum diameter, i.e. the one less influenced by the basal swelling, and the height for each fan shape (Table 1).

Tab. 1 - Fan shapes, percentages of their presence and correlations with height.
Tab. 1 - Forme identificate nella popolazione, percentuali di presenza e differenti correlazioni con le altezze.

Shape	Percentage	Correlation between minimum diameter and height
Rectangular	48%	df=33 r=0.86 P<0.01
Square	38%	df=26 r=0.82 P<0.01
Feather	14%	df=9 r=0.75 P<0.05

The good correlations seem to confirm that the diameters are valid biometric parameters to describe the growth of *P. clavata*.
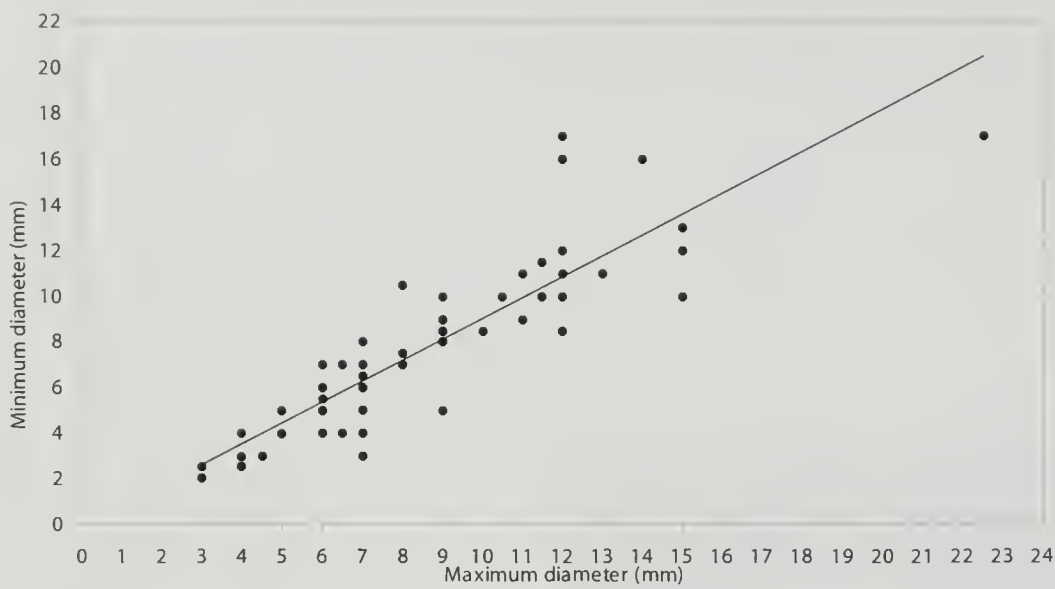
Fig. 2 - Correlation between the maximum and minimum diameters.
Fig. 2 - Correlazione tra i diametri minimi e massimi.

Biometric parameters

Among the biometric parameters obtained with the Quantimet photographic analysis, we decided to use fibre length to estimate the general growth of the colony. This variable had low variability, a good correlation with colony height (df=80, r=0.89, P<0.01) (Fig. 3) and was also the parameter most related to the colony complexity, expressed by the branched shape of the fan.
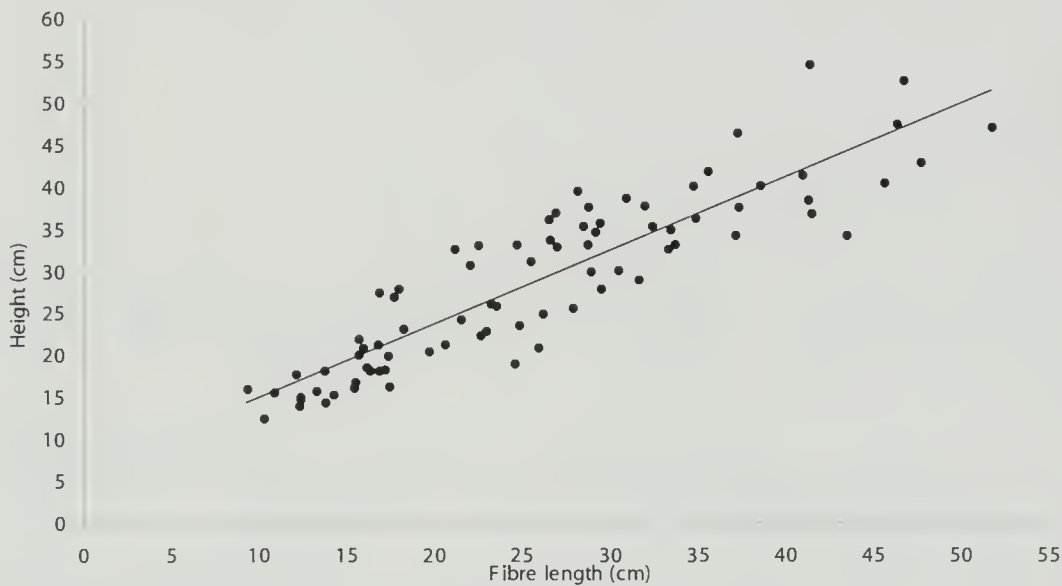

Fig. 3 - Correlation between fibre length and height of the colony.
Fig. 3 - Correlazione tra la lunghezza-fibra e l'altezza della colonia.

Average annual growth

The average rate of growth was calculated by the increase in height of the colony (Fig. 4) and by the increase in length of the arms of the fan, indicated by the fibre length.

The average annual growth based on height was 3.22 ± 2.26 cm (n=224), with negative values due to breakage and direct or indirect consequences of predation.

The average annual growth based on fibre length was 37.07 ±16.04 cm (n=47).
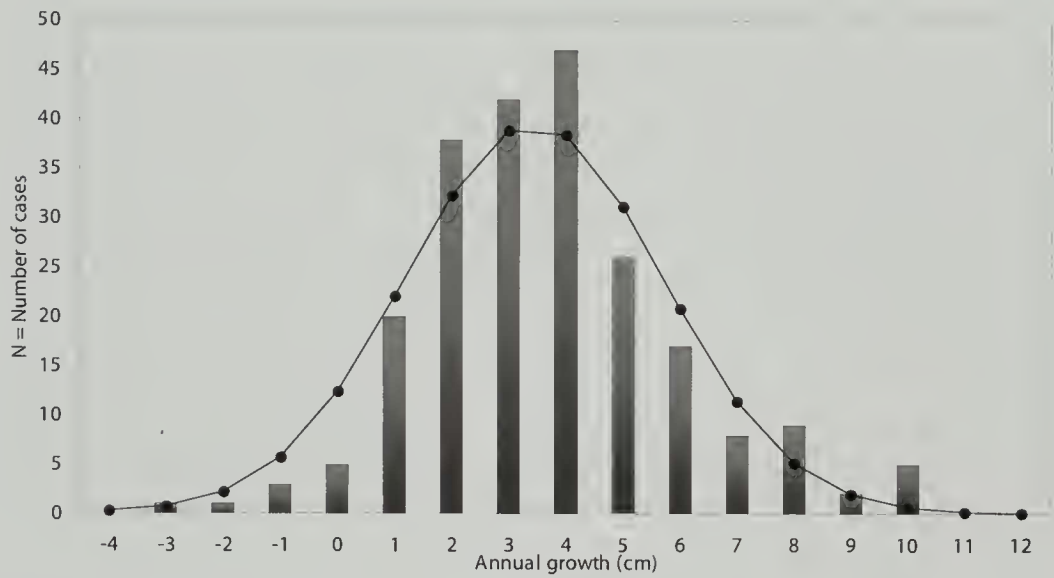

Fig. 4 - Average yearly growth rate.
Fig. 4 - Tasso di crescita annuale.

Average seasonal growth

In addition to annual growth, we also analysed seasonal growth (Fig. 5).

The average seasonal growth rate differed significantly between winter 2001 and summer 2002 (t-test, t=3.404, df=157, P<0.01) and between winter 2002 and summer 2003 (t=2.650, df=149, P<0.05). Therefore, growth was faster in winter than in summer.

Fig. 5 - Average seasonal growth rate.
Fig. 5 - Tasso di crescita stagionale.

Discussion

Basal diameter

The basal diameter is a good parameter to establish the age of the colony because it's directly related to the number of growth rings (Mistri & Ceccherelli, 1993). Besides both the maximum and the minimum basal diameters are also significantly correlated among themselves and with the height of the fan. In some cases a relative dispersion can be attributed to the presence of a fork immediately above the measured point, where the trunk tends to become particularly wide. This fork, which falsifies the proportionality between the diameters, seems to be related to the different observed morphologies and also reported by Velimirov (1976) in a study on *Eunicella cavolinii*. In fact, square fans bifurcate immediately above the basal swelling while the rectangular and feather-shaped fans maintain a single axis, at least in the first few centimetres.

Therefore, although influenced by endogenous factors like colony shape and by exogenous factors like water movement or food abundance (Mistri, 1995), the diameter (especially the minimum one) can be considered a good indicator of the growth of *P. clavata*. Moreover, it can be studied *in situ* without the use of invasive techniques.

Average annual growth

The mean annual growth in height was 3.2 ± 2.26 cm, slightly higher than the growth rate estimated by Mistri & Ceccherelli (1994) for a *P. clavata* population in the Messina Strait (2.7 ± 1.6 cm) and by Weinberg & Weinberg (1979) (1.8 ± 1.6 cm) in a study conducted at Banyuls sur Mer (France). In a subsequent study, the same Authors (Weinberg & Weinberg, 1991) reported an annual rate of linear growth in height of 3.6 ± 2.4, very near to ours, while Coma *et al.* (1998b) calculated an average annual rate of 1.8 ± 1.27 cm (range 0.2-6.4 cm) in 54 *P. clavata* colonies at Medes Islands (Spain).

The average annual growth in fibre length was 37 ± 16.04 cm. Since this measure has never been used in other studies on *P. clavata*, the only possible comparison is with the values obtained by Weimbauer & Velimirov (1995) for *E. cavolinii* (range 9.7-32.9 cm). Since the latter species has a much lower average annual growth rate (1.14 ± 0.44 cm) than *P. clavata*, it is not surprising that it also has a low rate of growth in fibre length.

Average seasonal growth

We observed that *P. clavata* grows more in winter (October-March), with low temperature and short photoperiod, than in summer, probably affected by environmental conditions, like the temperature or the light.

These observations are confirmed by a study of an *E. cavolinii* population in San Pancrazio Bay (Ischia), where Russo (1985) concluded that seasonal parameters like temperature and turbidity, influenced the colony growth. Similar results were obtained by Velimirov (1975), who studied a population of the same species at Filicudi: the analysis of variance showed that the average growth rate in the periods January-February and February-March differed significantly from the others, suggesting that the growth in winter is more dynamic than in summer.

These observations are confirmed by the internal structure of the axial skeleton

of the fan, consisting mainly of two strata: an internal spongy layer (medulla), due to the loose arrangement of the horny lamellae of gorgonin, and a more external hard layer (cortex), produced by the deposition of the lamellae in compact layers. The former corresponds to the slow summer growth while the latter reflects the rapid growth in winter (Grigg, 1974; Mitchell *et al.*, 1993; Mistri & Ceccherelli, 1993, 1994).

The same seasonal difference was found by Coma *et al.* (1998a), who observed an increase of the stomach contents in *P. clavata* colony members, and thus of the energy available for their growth, at the end of winter/beginning of spring. The same Authors (Coma *et al.*, 1998b) attributed the different annual growth rate to a series of endogenous and exogenous factors, including the annual cycle of plankton production, which presents two peaks, one in winter and a smaller one in spring. Grigg (1974) came to the same conclusion, i.e. that seasonal fluctuations in food abundance are one of the most important biotic parameters affecting the growth of the Octocorallia, especially the Gorgonacea, which are passive filterers (Koehl, 1984; Mistri & Ceccherelli, 1993) and essentially non-selective (Goreau *et al.*, 1971). Moreover, plankton fluctuations are influenced by various climatic factors: in winter, the higher input of nutrients produced by the stronger wave action and rainfall favours the growth of plankton; in contrast, the sea is calmer in summer and the inflow of river water drastically decreases. All this affects the growth of the gorgonians.

In summer, i.e. the peak reproductive period (Gili & Garcìa, 1985), the energy used for the growth is reduced to satisfy the energy demands of reproduction. *P. clavata* presents gonadal maturation between June and July in coincidence with the increasing temperature and in relation to the lunar cycle, with the maximum reproductive peak, i.e. expulsion of the eggs, in August (Coma *et al.*, 1995a,b). Therefore, we can assume that, in summer, the energy used for the growth by colonies that have already reached sexual maturity is reduced in favour of the very high energy investment in reproduction; this investment reaches 98% of the entire biomass (excluding the skeleton) but decreases in winter (Coma *et al.*, 1995a).

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